

LEARNING OF CHILDREN IN ADAPTATION
TO MIRROR REVERSALS

BY
EUGENIA KETTERLINUS

A DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS
HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
1931

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THE mirror drawing experiment has been considered of special importance for the study of the trial and error method of learning by adults. The assumption has been made that few habits have been established of hand and eye coordinations under conditions that require the observation of movements in the mirror. Especially is this true of the child under six years of age, who ordinarily makes few motor adaptations to objects seen only in a mirror. The analysis of the learning process of the child under such conditions is the problem of this investigation.

An historical survey of the literature on this problem, namely, the adaptation of the preschool child to the mirror situation, cannot be made, as no work has been published to date on the reaction of young children to mirrored presentations. The nearest approach to work with preschool children is that of Clinton (4) who continued the work of Pyle (11) with fourth to eighth grade children, down to third, second, and even first grade children. A brief review of mirror drawing as a psychological experiment is given.

Mirror drawing, as a bona fide psychological experiment, makes its first appearance in print in Henri's (7) monograph, *Ueber die Raumwahrneh-*

mungen des Tastsinnes, published in 1898. In this book, dealing with tactual space perception, only a page and a half is given to the mirror drawing experiment, which is simple in character but has all the essential elements of the later more elaborate set-ups. No data are given as to the number of subjects who tried this experiment, nor the number of trials they were given.

Henri (8) goes more into detail about the mirror drawing experiment in his article *Revue général sur le sens musculaire*, which differs somewhat from the original experiment. Instead of two points to be joined by a straight line, he used a straight line, drawn at an angle of 45° at the right of the paper, and asked his subjects to draw lines parallel to the model line. He had two subjects besides himself, and all three of them had considerable difficulty in drawing straight lines. Henri did not keep time but recorded the number of trials necessary before a good copy was made. He reports that in one case 200 repetitions were necessary before a straight line was achieved.

In 1905, Dearborn (6) used the six pointed star as the figure to be traced in his mirror-drawing experiment, but he did not publish a description of it until 1910. Dearborn considered the use of mirror-drawing as valuable in giving the student an opportunity for

first hand experience with the trial and error method of learning. He says: "There is some advantage in an experiment which will indicate that the trial and error method is, in certain conditions, regularly employed in adult human learning. The student is apt to get the impression from the usual discussion that trial and error, as a method of learning, is confined to animals and children."

In 1907-08 (not published until 1910), Burt (2) gave a series of tests, intended to test general intelligence, to a group of elementary school boys and to a group of preparatory school boys. Among these tests was one using a mirror. Burt gives credit for the idea of using a mirror to Mr. Keatinge but says he, himself, devised the test as used. This test differs from any used before in that there is no actual drawing. The set-up, aside from the mirror and screen, consisted of a thick cloth laid upon a firm table; on the cloth was placed a sheet of paper and upon the paper was pinned a sheet of stout millboard pierced with eight holes arranged in the form of a circle 20 cm. in diameter, with a ninth hole in the center. The reactor was required, using a blunt mounted needle to punch through the holes in the cardboard, thus leaving a pattern in the paper beneath. The holes had to be punched in a certain order, and the time taken to punch all the holes was kept. For the elementary school boys, Burt reports a correlation between this test and estimated intelligence of 0.67, P.E. .07; for the preparatory school boys a correlation of 0.54, P.E. .14.

In 1910, Starch (13) used mirror-

drawing for his experiment in cross-education. He used Dearborn's set-up and six pointed star. His procedure was to trace one star with his left hand and then he traced 100 stars with his right, tracing only one a day. Then he traced one star with his left hand. His right hand improved 92 per cent in accuracy and 84 per cent in speed, his left hand improved between the first and second trials 81 per cent in accuracy and 85 per cent in speed.

D. S. Hill (9) used the mirror-drawing experiment with thirty elementary and thirteen preparatory school boys and reported the experiment very satisfactory to illustrate the learning process.

On December 8, 1913, Hill (10) had one of the same subjects whom he had used in the above experiment repeat that experiment in order to see how much relearning would be necessary. This subject had had his last trial in mirror-drawing on December 20, 1910, when his time had been 24 seconds. On December 8, 1913, after an interval of nearly three years, his time on the first trial was 36 seconds. His original first trial had been 107 seconds. Hill concludes from this that there is very little trial and error learning after the first few trials.

Inappropriate as it may seem, it is the work of Weidensall (14) on *The Mentality of the Criminal Woman* which was a real contribution to make toward the understanding of the reactions of certain children in the pre-school group used in this investigation. Dr. Weidensall says that the mirror-drawing test served better than any other used at Bedford to isolate the

women who were incapable of sustained effort or emotional control, and certainly the behavior of some of my small subjects suggests that the mirror situation is an excellent one for revealing emotional instability.

Dr. Weidensall gave the mirror-drawing test to 69 of the Bedford Reformatory women, 16 college maids, and 36 college students. The instructions were the same as given by Whipple (16). In both first and last stars (5 in all), both as to time and errors, the three groups are consistently arranged in the same order with respect to percentile records, average and limiting scores. The students have the fewest errors and quickest time, the maids are intermediate and the reformatory women have the slowest time and greatest number of errors.

"The test isolates" says Dr. Weidensall, "the extremely low grade feeble minded, who, no matter how hard they try, cannot succeed in tracing a precise star. The epileptics have a characteristically bad time and their stars are all knotted up with 'blind spots' where they are caught and held indefinitely. . . . Chiefly however, is the test of interest in the case of those who are clever enough but too unstable to trace the star well. These are invariably the girls who are difficult to manage in the institution. The tracing goes well enough until suddenly, at a hard point, the pencil starts, and persists upon going, in the wrong direction. The subject then tugs and pulls, grows more and more irritated, disturbed and excited, makes big black circles and unprofitable markings, soon loses all control of herself, and finally throws down the pencil and gives up. . . . No other test has so conspicuously precipitated this state of instability on the part of the more excitable inmates, who work well as long as they meet with easy success, but who have not reserve force or stability in the fact of a difficult

situation which demands of them patience and perseverance."

Cooke (5) also has something to say regarding the diagnostic possibilities of mirror-drawing experiments. He gave the star to a group of high school boys and reports that: "As a personal study this test was very interesting, showing traits of nervousness, carefulness, persistency, and lack of concentration."

In 1918 a description of a new apparatus is given by G. R. Wells (15) which has the advantage of automatically counting the errors made. This device consists of a small brass star inside of a larger brass star with a cement path between the outer edge of the small star and the inner edge of the large star. The cement is flush with the top of the stars. The subject is to trace the cement path with a stylus, which is hooked up to a recording device, so that when it gets off the path onto the brass that error is recorded. This apparatus has the disadvantage of giving no permanent record of how far off the path the subject wanders.

An exhaustive study of tracing the six-pointed star, by G. S. Snoddy (12), was published in 1920. The apparatus used was something on the order of the one described by Wells (15), a brass star being used on glass. Snoddy had 21 subjects, 9 graduate students used for objective data and introspection, and 12 advanced students for objective data only. The most interesting data in this investigation from our point of view are the introspections, which are suggestive. As they are very long, only one will be quoted. A

representative one seems to be Observer 3, who, on the first day of his practice had this to say:

"As soon as I heard the signal, I proceeded to follow the arrow. Then my stylus struck the niche up on the first side. I did not know I was moving in that direction until I struck the side; I tried to push away but found I was pushing against the side. I attempted two or three times to get away but could not; I thought the electric current must be holding the stylus against the sides; I was aware of intensive strains in my arm and the whole affair was very unpleasant. Finally, I gave up and relaxed for a time. I again looked at the star and found that my stylus had moved partly out of the niche during my relaxation. I attempted to get away but drove the stylus back into the niche again. Then the muscles of my arm and shoulder tightened and, with a quick movement, I pulled the stylus out of the niche and down past the arrow."

For a less extended historical survey, read Carmichel (3), and since his article appeared we have the interesting work of Bray (1) and of Clinton (4) published in 1928 and 1930 respectively. Bray's investigation is a combination mirror-experiment and accuracy-experiment, devised to study transfer of learning from hand to foot. The procedure was the same for both the hand and foot experiments. In the hand experiments, the subject sat at a table placed against a wall; on the wall was a target consisting of a cross drawn on a sheet of white paper (in later experiments the cross was changed to a simple vertical line bisecting the paper), which could be seen only by means of a mirror placed on the left. The subject placed his arm under the screen on a marked spot, directly in front of the center of the

cross. In his hand was a pencil, with which he was told to hit the cross in time to a metronome beating at 72 per minute. Each subject was given 10 hits, then a rest period of 2 minutes, and then began again with a new target. Each 10 hits was called 1 trial, and 10 trials were given a day. In the foot experiment, the subject sat in an elevated chair with his thigh in a rest. This rest was directly in front of the target, so that the foot hung in front of the mark. A group of 14 subjects were given 60 trials with the right hand and then 40 trials with the right foot. A second group of 14 subjects were given only 40 trials with the right foot only. The group which had had the hand practice showed increased initial accuracy with the foot. Other similar experiments were made and a transfer of learning from right hand to right foot was shown.

Clinton used a pattern having the numbers 1 to 24 inclusive, arranged in two circles. Numbers 2, 5, 8, 11, 14, 17, 20, and 23 made up the small inner circle, and numbers 1, 3, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, and 24 made up the large outer circle. A small dot located at each numbered point of these circles was to be cut by a continuous line from 1 to 24. Each subject's score was the number of lines completed during a five minute period, and if a whole pattern was completed within the time limit, a second sheet was given. For grades 1, 2, and 3, a pattern sheet was designed with numbers from 1 to 15.

The data were obtained from 1903 unselected students in four school systems, consisting of one group of ele-

mentary school students, two groups of high school students and two groups of university students in educational psychology. Clinton finds practically no relation between mirror-drawing ability and general intelligence as measured by I.Q.'s. The most interesting feature of Clinton's work is the indication that age is an extremely important factor in mirror-drawing ability. He has averaged the scores in each year from six to seventeen, for boys and girls separately, and finds a definite improvement in the score at each age, except that the 12 year old boys did not do quite as well as the 11 year old boys.

APPARATUS AND PROCEDURE

Three forms of procedure were used, graded from a simple to a difficult performance. This grading was conjectural but based upon experience with children between the ages of one and a half to six years of age, and upon knowledge of their abilities as measured in other test situations. It was known that they could not trace a star, nor even a straight line accurately, in direct vision.

The subjects were children in the Child Institute of the Johns Hopkins University, ranging in age, at the time of the beginning of the experiment, from two years and one month to five years and four months. Only one child was over five, the next younger being four years and seven months. There were 19 boys and 8 girls.

Twenty-eight children started this experiment, only one child did not complete it. This one child left school after the second week of the experiment, because of illness and did not

return. Of the 27 children who completed the experiment, twelve were below three years of age, six were below four years of age, eight were below five years of age, and one was over five.

The apparatus for each form of procedure will be described in the section giving the experimental results for that form.

PROBLEM I

A mirror, 30 by 25 centimeters, hung between two uprights so as to permit adjustment at various angles, was placed at the back of a table 51 centimeters high and 43 centimeters square. In front of the mirror was placed the board, 36 centimeters wide and 33 centimeters deep, containing the test objects. On the extreme left of this board, and midway from the front to the back, a tin cup 6.5 centimeters in diameter and 5 centimeters in height was screwed. The outline of the three objects was drawn on the board so that they could be replaced in exactly the same positions. These objects were a spoon, 5.5 centimeters in length, placed 28 centimeters from the front edge of the board and 18 centimeters from the right hand edge; a white pearl button 2 centimeters in diameter placed 20 centimeters from the front edge of the board and 8 centimeters from the right edge; and a ball 2 centimeters in diameter, made of clay with one side flattened so that it would not roll, placed 9 centimeters from the front and 20 centimeters from the right. A cross was made at the front of the board 7 centimeters from the right edge. This board, with the objects in position, was placed on the table with its front edge flush with the

front edge of the table. For a screen to cut off direct vision, a piece of thin board was used, as being more substantial than the usual cardboard, in anticipation of the children leaning on it and trying to look under. This board was 38 by 25 centimeters and had a strip of light wood nailed to it and extending beyond it 10 centimeters, which was clamped into an ordinary adjustable laboratory support fastened to the right of the table.

The first time that the child was brought in to "play the game," the mirror was on another table and the screen swung around to the right out of the way, so that the board with the cup and three objects was in plain sight. This was for the control test, each child being given one trial with direct vision so that the time normally required by the child to complete the task would be known and could be used to check the amount of slowing up caused by the mirror reversal. The child was seated in a chair, its seat 35.5 centimeters from the floor, which was then moved up close to the table. The observer then took the child's right hand, placed it on the cross marked on the board, and held it there, saying:

"See the things on the table, when I say 'Go' you are to pick up the ball and put it in the cup, then pick up the button and put it in the cup, and then the spoon, as quickly as you can. Understand? You are to pick up the ball and put it in the cup, then the button, and then the spoon.

Get ready—Go—Put the ball in the cup."

If necessary, that is, if the child hesitated after the ball was put in the cup, the observer prompted with "Now the button" or "Now the spoon" or both, as the occasion required. Time was

kept with a stop watch from the release of the child's hand at "Go" to the sound of the spoon hitting the bottom of the cup.

Then the child and chair were pushed back, the child being allowed to get up if he wanted to. The observer swung the screen around into position, replaced the objects on the board, put the mirror on the experimenting table and moved the child up to the table again, saying,

"I want you to do exactly what you did before, first put the ball in the cup, then the button in the cup and then the spoon, but now you cannot see them except in the mirror, which makes things look differently, and you will have to watch where your hand goes in the mirror so that you can pick them up and put them in the cup. Can you see the ball and the button and the spoon and the cup?" If the child said "No," the mirror was adjusted until he could see all four. Then the observer placed the child's right hand on the cross and asked if he could see that, too. Then the observer said, "When I say 'Go' do just what you did before, pick up the ball and put it in the cup, then the button and then the spoon. Ready,—go."

As before, the observer prompts as to which object is to be sought next. Time was kept from the release of the child's hand to the tinkle of the first object as it landed in the cup; from that second until the next object was dropped into the cup; and from the placing of this object until the sound of the final object hitting the bottom of the cup. Time was the only score used because, as there was no record of the child's movements made, no accurate count could be made of errors; but after each trial, the observer wrote down anything unusual that occurred, such as the child's dropping an object,

or knocking it off the board, or changing from one hand to another, or persistently overreaching, etc.

Two trials were given each day, the second trial immediately after the first. After the objects were replaced, the observer said, "You did that very nicely, now see if you can do it even better this time. Do just what you did before." The trials were given in

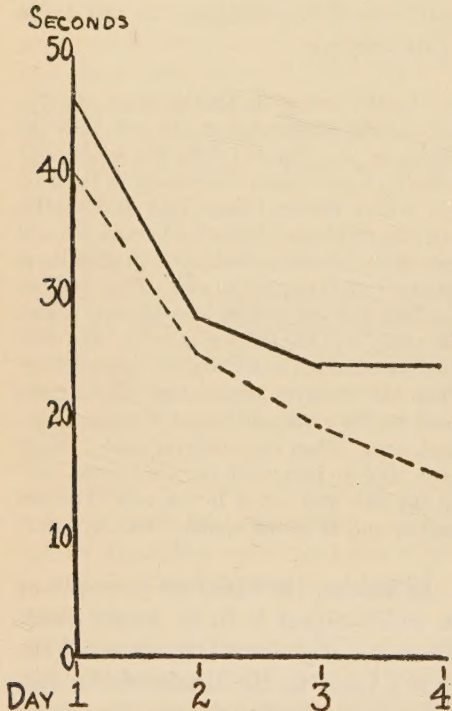


FIG. 1. MEAN TIME, FOR PUTTING OBJECTS IN CUP

—— first trial;----- second trial

a series of four days, one week apart. This schedule of one week apart was adhered to as nearly as absences and holidays would permit, and in the majority of cases was carried out exactly.

Results

The first experiment shows conclusively that four, three, and even two

year old children can learn to inhibit established habits and can rapidly acquire new ones. The mean score for all three age groups combined shows a definite improvement, not only from day to day, but also of the second trial over the first (see fig. 1). Taking the age groups separately, we find a somewhat different picture, although the final result is the same, that is, the final mean score for each group is the lowest mean score for that group. The four year old group shows the fewest irregularities, which might be expected on the basis of their comparative ma-

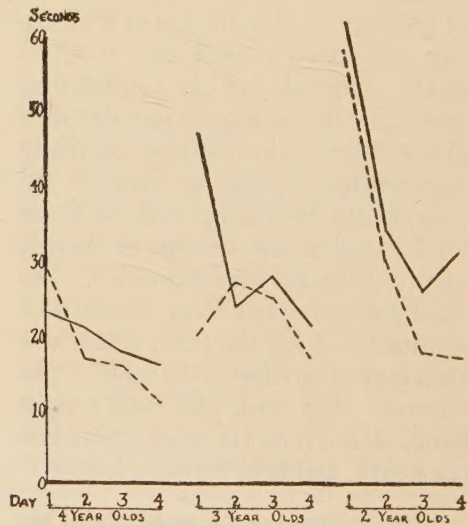


FIG. 2. COMPARISON OF THREE AGE GROUPS

—— first trial;----- second trial

turity, but the three year old group shows more irregularities than does the two year old group, which may be due to the influence of individual differences because of the few subjects in this group. (See fig. 2).

The mean scores of the four year old group show an improvement on each successive day, but on the first day the second trial is a decided slump over

the first, due to subject D1's getting badly "lost" trying to reach the spoon, and subject F having a similar difficulty with the button.

In the three year old group there is a slight regression in the first trial on the third day, and the second trial on the second day is not only worse than the second trial on the first day but is inferior to the first trial on the same day. The second trial improves slightly on the third day but not up to the standard set by the second trial on the first day. The vagaries of the second trial on the second and third days are due to one subject, I, who got stuck on the ball on the second day and the spoon on the third day. The explanation of the slowing up of the first trial on the third day is that three subjects, I, L, and Ll, slowed down on their time for putting each object into the cup.

The two year old group shows a consistent improvement from day to day on the second trial and on the first trial with the exception that the fourth day's score is five seconds slower than the third day's score.

All the mean scores referred to above are for the complete test, that is, the time required to put all three objects into the cup. The time for putting each object into the cup was kept for two purposes, first, in order to show up wide fluctuations in scores, for which it has proved invaluable, and second, on the theory that one position on the board might offer greater difficulties than another. This latter idea is not supported by the facts, for a careful scrutiny of the mean scores for specific objects in all three age groups combined shows no particular differences in their relative difficulty, therefore

all scores mentioned, unless otherwise specified, will refer to the time required to complete the test.

Although there are decided individual differences shown they are not as great as were anticipated. The subjects who got "lost" once, tended to do so again. In all three groups there is not one case in which a subject gets "lost" after the second day, unless he has been "lost" earlier, and only one case in which the first trouble of this kind appears on the second day. On the other hand those subjects who got lost on the first day, in spite of marked improvement, might suddenly get badly stuck on one object even on the fourth day.

Four year old group. The shortest time on the first trial in the four year group was made by subject C, four years and five months old. This time was 9 seconds and he also made the shortest final trial, time 6 seconds. (See table 1.) It is interesting that 6 seconds is also his time without the mirror. This subject is the only one who brought his mirror time down to his time without the mirror, although a number of others reduced their time to within a few seconds of their direct vision time.

The longest first trial in the four year group was made by subject B, aged four years seven months. Her time was 50 seconds, twenty-nine of which were spent trying to locate the button. On the final trial she had reduced her total time to 17 seconds. For a comparison of her complete performance with that of subject C consult figure 3. The longest time taken by any child in the four year group was in the second trial on the first day by subject D1 who took 66 seconds. He

TABLE 1

SUBJECTS	1ST DAY		2ND DAY		3RD DAY		4TH DAY		TIME WITHOUT MIRROR
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
Four year old group—time in seconds									
A	23	20	42	20	25	35	20	14	8
B	50	31	22	17	22	22	42	17	6
C	9	12	12	19	18	11	11	6	6
D	17	25	22	15	15	15	11	9	6
D1	13	66	18	15	15	10	13	9	6
E	35	30	33	22	30	16	19	13	9
F	26	56	17	18	17	13	15	9	8
G	18	9	12	18	10	14	8	7	5
H	20	15	18	9	12	11	10	12	5
Totals...	211	264	196	153	164	147	149	96	61
Mean....	23.4	29.3	21.7	17.0	18.2	16.3	16.5	10.6	6.7
Three year old group—time in seconds									
I	54	55	45	79	56	77	32	23	11
J	22	18	13	10	12	12	11	10	5
K	43	9	25	23	14	10	22	27	7
L	120	18	21	21	30	14	19	14	7
L1	17	13	20	15	40	20	16	13	7
M	29	12	19	17	16	22	27	20	11
Totals...	285	122	143	165	168	155	127	107	48
Mean....	47.5	20.3	23.8	27.5	28.0	25.8	21.1	17.8	8.0
Two year old group—time in seconds									
N	51	28	10	18	39	15	11	12	9
N1	24	23	64	29	46	23	64	21	6
O	20	20	25	15	20	26	20	10	9
P	35	13	21	25	34	20	20	23	7
Q	21	30	37	24	22	11	28	13	9
R	179	183	43	45	27	17	82	25	10
S	25	13	30	16	20	14	24	13	12
T	122	81	19	18	28	18	21	15	8
U	40	27	20	35	16	10	15	13	10
V	80	222	117	78	18	37	20	15	14
W	37	21	22	32	20	18	25	10	9
X	118	43	20	30	30	18	49	35	17
Totals...	752	704	428	365	320	227	379	205	120
Mean....	62.6	58.6	34.0	30.4	26.6	18.3	31.5	17.0	10.0

reduced his time on the final trial to 9 seconds, his time without the mirror was 6 seconds.

Of the nine subjects in the oldest group, eight made their best score in the final trial, and one subject made his best time in the second trial of the second day. This was subject H, the youngest child in this group. He did remarkably well throughout the experiment, his highest score, which was on the first trial on the first day was 20 seconds and his final score 12 seconds.

Three year old group. The shortest first score in the three year group was made by subject Ll, three years and seven months old. (See table 1). Her time was 17 seconds, which is considerably slower than the best first score in the four year group. Subject Ll did not make the best final score by four seconds, and her final score, 13, she had equalled on her second trial on the first day. Her time without the mirror was 7 seconds.

The longest first score in the three year group was made by subject L, aged three years and eight months, time 120 seconds, more than twice the longest first score in the four year group. This is the longest time on any trial in this whole group. She reduced her time in the second trial on the third day and in the final trial to 14 seconds, her time with direct vision was seven seconds.

The most consistent good record in the three year group was made by subject J, aged three years and eleven months. His highest score in the whole series being 22 seconds, made in the initial trial, and his lowest score 10 seconds, made in the second trial on the second day and in the final trial.

The most erratic record, due to the subject's tendency to get "lost" was made by Subject I, whose worst score was 79 seconds, on the second trial on the second day, and whose best score was his final score of 23 seconds. Time without the mirror eleven seconds. For a comparison of the complete performances of these two contrasted subjects, see figure 3.

Of the six subjects in the three year old group, only one made his best score in the final trial, subject I. Three subjects, J, L, and Ll, did as

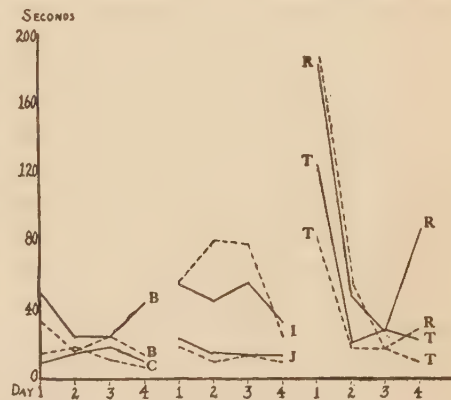


FIG. 3. EXAMPLES OF INDIVIDUAL DIFFERENCES FROM EACH AGE GROUP

—— first trial;----- second trial

well in the final trial as they had done once before. Two subjects, K, who made the best time of all in this group, 9 seconds, and M, made their best time on the second trial on the first day. Subject M, whose record shows the least consistent improvement without any spectacular set backs, is the youngest child in this group, being three years and four months old.

Two year old group. The lowest first score in the two year old group was made by Subject O, aged two years and nine months. (See table 1.) The

score was 20 seconds, not much slower than the shortest first trial in the three year group. This subject had little difficulty with the test, his poorest time was 26 seconds, made on the second trial of the third day, and his final trial, 10 seconds, was one of the two best final trials made by this group. His time without the mirror was 9 seconds.

The longest initial trial, 179 seconds, in the two year group was made by Subject R, aged two years and eight months. This time is almost a whole minute slower than the longest first trial in the three year group. The slowest time in this whole group was made by this subject on his second trial on the first day, 183 seconds, Subject R's final score was 25 seconds, but his best score, made on the second trial on the third day, was 17 seconds. A comparison of R's performance with Subject T's (fig. 3) is interesting as an example of two subjects who both start badly, but one of whom shows almost steady improvement while the other gets into difficulties even on the last day.

Half of the subjects in the two year old group made their best score in the final trial, one did as well in his final score as he had done once before. Of the other five subjects, one made his best score on the second trial on the first day, three made their best scores on the second trial of the third day, and one on the first trial of the last day.

Summary

Clinton's conclusion that mirror drawing ability develops from year to year is strikingly upheld by a com-

parison of the performance of the three age groups. In the first trial there is practically no overlapping of the groups,—although on the third day the two year olds do better than the three year olds by two seconds. In the second trial there is some overlapping between the three year group and the other two groups, but none between the two and four year groups.

PROBLEM II

The subjects were the same as those used for Problem I, except that five had left school or were absent for such long periods that they could not be used. Of these children, one belonged to the four year old group, two, unfortunately, belonged to the three year old group, reducing it to only four members, and two were in the two year old group. This left 22 subjects who completed Problem II.

Apparatus and procedure

For the foot experiment, a large mirror was used, 92 centimeters square. This mirror stood upon the floor inclined against the wall of the experimenting room. Suspended from a wire above the mirror was a curtain which could be lowered to conceal the mirror. In order that the subjects would have something to hold on to while standing on one foot, an adjustable rack was used. This rack consisted of two boards, 15 centimeters wide and 92 centimeters long, nailed at right angles to the ends of a thick plank of corresponding width and 61 centimeters long which was used as the base. The boards used as uprights had holes 1.5 centimeters in diameter bored 5 centimeters apart in a per-



pendicular line to the base, along the outer edge. An iron rod inserted in the holes at about the right height for the child to hold thus gave a solid support for the child to grasp with both hands. In this way he could stand on his left foot and move his right foot freely without losing his balance (Plate I). Only three heights were actually used in this experiment. The stand was placed 123 centimeters in front of the mirror.

On the floor directly in front of the stand was laid a piece of beaver board 54 centimeters wide by 67 centimeters long, to which the sheets of paper for individual records were fastened with thumb tacks. The paper used for the records was Congress linen bond, cut in sheets 48 centimeters wide by 60.5 centimeters long. In the center of each sheet of paper a circle was drawn 10.5 centimeters in diameter. This circle was filled in solid with yellow paint.

The disc which the subject was to push with his foot, was of wood, 10.5 centimeters in diameter, and one centimeter in thickness. It was painted yellow to correspond with its destination. In the center of the disc a hole was bored to permit the insertion of the point of a large lead pencil. This pencil had a wire loop fastened just below the eraser, which was turned down toward the point of the pencil. A heavy strip of rubber, in length a little less than twice the distance from the loop to the point of the pencil, was passed through the loop and then both ends were pinned down together to the disc, as close to the edge of the hole as possible, in order that the pull of the

rubber would force the pencil through the disc and thus make a mark whenever the disc was pushed along a smooth surface. Of course the pencil had to be adjusted from time to time, the point needing to be sharpened and the rubber stretched tighter to maintain the same tension, as the pencil grew shorter.

For a screen, a piece of care board 41 centimeters wide by 80 centimeters long was used. This screen was laid above the record sheet 53 centimeters from the floor, one end of the screen resting on a table, the other supported by a wooden box of corresponding height, one edge flush with the edge of the stand. In the case of the smallest children, the bar of the support was flush with the edge of the screen. Clamped to the edge of the table, underneath the screen, was an electric light, used on dark days to counteract the cutting off of light by the screen.

No record, other than time, was kept on the trial without the mirror, because the movement was so simple that there was practically no variation. For the direct vision trial, therefore, one record sheet was kept permanently fastened to a piece of beaver board and used over and over again. When the subject entered the experimenting room, the curtain was lowered over the mirror and the try-out sheet in position on the floor in front of the stand. The screen had been removed. The observer said: "Stand in here" indicating the space between the two uprights of the stand, "and hold on to the rod with both hands. Then you are to put your foot on this yellow block and push it onto the yellow cir-

cle, like this." (Demonstration). "Now, when I say 'Go' push the block onto the circle. Ready, Go."

After this had been accomplished, usually within a few seconds, the practice board was removed and replaced with the other similar board, with a fresh record sheet fastened to it with thumb tacks. The screen was put in position, the curtain lifted from the mirror, the disc placed on the record sheet in the lower right hand corner, with its rim 3 centimeters from each edge of the paper, so that movement could be made in any direction. The following instructions were then given: "Now do just what you did before, put your foot on the block and push it onto the yellow circle, when I say 'Go,' but this time you must look in the mirror to see where your foot is. Ready, go." Time was kept with a stop watch from "Go" until the subject completed the task to his own satisfaction, or until three minutes were up.

Only one trial was given each day, and only three trials were given, at intervals of three days with some exceptions. If a subject had his first trial on Thursday, he had his second on the next Monday and his third on the following Thursday.

The problem of scoring the records was a difficult one. A wooden frame was constructed the size of the record sheet. Tacks were placed on the frame at intervals so that a string pulled taut across the frame made blocks 15 centimeters square. At least the bottom and middle rows were square, the top row was several centimeters larger from top to bottom as the paper was not square, but this did not

matter because the subjects could not reach quite to the middle of the top row. There were four squares from left to right and three from top to bottom. The middle line from top to bottom ran directly through the center of the circle. Thus, if the disc were pushed straight to the circle, it would traverse but one square. If the disc were pushed far enough to the left to get into the second square from the right side of the frame, that was counted one error to the left, if it were pushed into the third square from the right side of the frame that was counted two errors to the left. If the disc were pushed up into the middle square at the right, that was counted one error "up," and so on. Of course this system takes into account only gross errors with one exception: if the disc were moved perceptibly to the right, or down, in the starting square this counted one error, as it could not possibly be moved more than three centimeters in these directions, as it came up against the box or stand; but as the movement was a gross one, this method seems admissible. Errors were only counted when the goal was attained within the time limit of three minutes. In the case of six subjects in the two year group, the stand was placed six centimeters on the record sheet so that the subjects could reach the goal.

Results

The results of the second experiment show a more definite cleavage in the abilities of the age groups than do the results of the first experiment. The three and four year old groups can be said to have mastered the problem in

the three trials given, with the exception of one subject, J, whose difficulty was emotional and whose case will be older groups on the first day. That is, the average time of the 9 subjects who completed the experiment on the

TABLE 2
Time and error record for age groups in experiment II

SUBJECTS		TIME WITHOUT MIRROR	1ST DAY		2ND DAY		3RD DAY	
			Time	Errors	Time	Errors	Time	Errors
		<i>seconds</i>						
Four year group	A	8	78	2	103	3	27	3
	B	10	127	6	9	1	9	4
	C	3	21	4	14	1	17	3
	D	4	20	3	11	4	7	1
	E	15	168	5	32	3	30	5
	F	5	18	5	18	4	5	3
	G	15	45	8	109	9	58	5
	H	3	119	8	97	5	25	1
Totals.....			596	41	393	30	178	25
Mean.....			74.5	5.1	49.1	3.7	22.2	3.1
Three year group	I	8	66	5	85	5	9	2
	J	10	DNC	—	DNC	—	DNC	—
	L	5	12	2	10	0	10	1
	M	4	34	1	62	12	50	7
Totals.....			112	8	157	17	69	10
Mean.....			37.3		52.3		23.0	
Two year group	O	8	17	1	DNC	—	81	7
	P*	10	DNC	—	16	2	59	3
	Q	10	DNC	—	DNC	—	110	5
	R	8	DNC	—	72	9	99	4
	S	5	86	3	DNC†	—	10	3
	T*	3	66	8	103	5	35	5
	U*	3	25	1	17	4	17	1
	V*	11	DNC	—	DNC	—	DNC	0
	W*	7	70	1	93	12	13	2
	X*	4	DNC	—	DNC	—	40	3
Totals.....			264	14	536	32	669	33
Mean.....			52.8		89.3		74.3	

* These subjects had the shorter distance.

† Completed after the time limit.

discussed later. The two year old group on the other hand seems, on the third day, to have reached about the stage of performance shown by the two third day was 74.3 seconds and that of the four year old group on the first day was 74.5 seconds; the three year group (three subjects) has a lower

time, 37.3 seconds, due to individual differences, on the second day their time goes up to 52.3 seconds. In the two year old group, on the first day only, half of the subjects completed the experiment, the other half either becoming hopelessly involved in wrong movements or giving up after placing the block less than half-way on the circle. On the second day, 6 subjects succeeded in reaching the goal within the time limit and on the last day all but one were successful.

Both the average time and the average number of errors made by the four year old group shows a steady decrease from day to day as is shown in table 2. This is especially true of the time record, for although the errors decrease they do not fall off as rapidly as the time. In individual cases, there seems to be a discrepancy between the number of errors made and the time taken to finish the task. For example, in the four year old group on the first day, subject H makes 8 errors in 119 seconds, whereas subject F makes 5 errors in 18 seconds. This apparent disproportion is due to the fact that in this experiment a subject tended to become bewildered when his foot went in the wrong direction, and frequently stood without moving at all for considerable periods. In addition to this tendency to stand still on the part of the cautious subjects, there was the over activity of the quick moving child who kept moving his foot regardless of where it went, consequently reaching the goal in less time but with more errors. These two factors are important in all three groups.

In the four year old group, five subjects, A, D, E, F, and H made their

best time score on the last day, and D, F, G, and H also made the fewest errors on the last day. The other subject, A, made his fewest errors on the first day. The fastest first score made in this group was 18 seconds, by subject F, who also made the best time on the last day, 5 seconds. Subject B was the slowest on the first day, taking 127 seconds, but she reduced this to 9 seconds the second day and took 9 seconds again on the last day.

The three year old group was composed of highly individualistic subjects. Subject J, after 65 seconds of fruitless effort, gave up, saying: "I don't want to do it any more. I want to go back to the other room." He kept on refusing to try any more until his three minutes elapsed. On the second day, he tried for 31 seconds, and then refused flatly to make any further effort. On the third day, he refused even to start. This subject is both spoiled and stubborn, and would not try to overcome the difficulties. In contrast to J's behavior is that of S who struggled on, almost weeping but determined to finish, succeeding in 3 minutes 50 seconds. Because of the time limit, he had to be scored D.N.C., but he was so absorbed and anxious to succeed that the observer let him continue over time.

The three year old group also contained subject I, whose tendency to get "lost" had appeared in the first experiment, and who ran true to form on the second day, running his time up to 85 seconds when it had been 66 seconds on the first day. He redeemed himself on the last day, cutting his time to 9 seconds and making only 2 errors. The only errorless record

made in the whole experiment belongs to subject L in this group. She also made the fastest time on the first day in any group, 12 seconds with 2 errors. On the second day she did it in 10 seconds with no errors, and on the third day in 10 seconds with 1 error. The other subject in the three year group, M, made the goal in 34 seconds with only 1 error on the first day, which must have been chance, because on the second day he wandered all over the paper, making 12 errors, and on the last day he improved only a little, bringing his time down to 50 seconds and his errors to seven.

vanquished. There is only one subject, U, in this group who made a consistently low record in both time and errors. All the others, on one day at least, took over 50 seconds except the youngest child in the group, X, who on the last day, after two failures, solved the problem in 40 seconds with three errors.

An analysis of the direction in which the errors were made shows the left predominate. (See table 3.)

Summary

The second experiment shows all three age groups learning new coördi-

TABLE 3
Analysis of errors

	LEFT	UP	DOWN	RIGHT
Four year old group.....	41	10	19	26
Three year old group.....	13	8	12	2
Two year old group.....	26	22	23	15
Total all groups.....	80	40	54	43

The situation which developed in the two year old group is difficult to account for, in view of the performance of this group in the first experiment. Had the two year olds been unable to learn the new coördinations thrust upon them by the mirror, well and good, but they learned it with the hand movement, although more slowly than did the older groups, and so just why the foot movement should prove more baffling to them seems obscure. On the first day only half the group met with success, on the second day two more were successful but one who had succeeded the first day failed, and on the third day only one remained

nations, but with more individual inconsistencies than appeared in the first experiment. This is probably due to there being more of an element of chance success in this experiment, where one chance movement in the right direction brought success, whereas in the first experiment three movements had to be made. Skill in foot movements is probably less developed than in hand movements, and the greater variability might be expected under such conditions. A study of the acquisition of skill in this situation by an adult might throw light upon the relative difficulty of hand and foot coördinations.

PROBLEM III

The subjects in this experiment were the same as those used in Problem II, that is, 22 children ranging in age from two years and one month to five years and four months. Seventeen of them were boys and 5 were girls.

Apparatus and procedure

The set-up for this experiment was the same as that for the first experiment, except the task to be done and the materials for that task. The same table and chair, the same mirror and screen were used as in Problem I. In place of the board, cup, and three objects, a sheet of white paper 35.5 centimeters long by 21.7 centimeters wide was fastened to the table with thumb tacks, the long edge flush with the front edge of the table. On the paper was a path, 4 centimeters wide, running the length of the paper. At one end this path was in the center of the paper, and starting from that end as the right hand end the path ran 10 centimeters and turned at a right angle to the left for 3.5 centimeters, turned another right angle to the right, continued straight for 9 centimeters, turned another right angle to the right, ran straight for 9.5 centimeters and turned at a right angle to the left and continued straight to the edge of the sheet. This was the direction used for the main part of the experiment. For the control test without the mirror, the paper was reversed so that the path started in the lower right hand corner.

A toy cannon, its two wheels 2.3 centimeters apart, was used to push along the path. Underneath the cannon and between the wheels a pencil stub

was fastened so that a line was drawn as the cannon was moved along. When the child came for the first time for this experiment, the screen was swung around to the right out of the way, the paper was in place on the table, with the path starting in the lower right hand corner. After the child was seated, the observer said, "See this road that is drawn here on the paper? I want you to push this cannon along that road as fast as you can without getting off the road. Now, hold the cannon this way." The child's fingers were placed around the cannon just above the pencil; "and when I say 'Go' push the cannon along the track, and be sure to stay in the road." Then observer places child's right hand, now containing the cannon, in the middle of the path at the edge of the paper, and says, "Ready, go," at the same moment releasing the child's hand. Time was kept with a stop watch until the cannon reached the other end of the paper, or for the two year olds until three minutes elapsed.

Then the paper was replaced with a fresh sheet turned around the other way, the mirror was put on the table and the screen swung into position so that the path was concealed from view except in the mirror. The child was moved close up to the table and asked, "Can you see all of the road in the mirror?" If not, the mirror was adjusted until he could see the whole path. Then observer placed the cannon in the child's hand and placed the hand containing the cannon in position in the middle of the track at the end of the paper, saying, "When I say 'Go,' do what you did before, push

the cannon along the road, being sure to keep in the road, but now you can only see it in the mirror, which you remember makes it look different. Ready, go." The hand was released at "Go." Time was kept with a stop watch until the cannon reached the other end of the paper or until five minutes had elapsed for the three and four year olds and three minutes for the two year olds. Occasionally, the observer reminded the subject that the cannon must be kept in the path.

Two trials were given with the mirror each day, for four days, at approximately three day intervals. That is, the experiments were made on Mondays and Thursdays for two consecutive weeks. In order to score the record of the cannon's meanderings left on the paper by the pencil, the following method was used. A scale of three units was made, each unit being one-third of the distance from the path to the top of the sheet, at the right hand end when the paper was in position for the mirror experiment. The scale was marked on a piece of paper and used to measure the distance the cannon had been pushed from the path. If the cannon were pushed off the track but not further than a distance of 2.8 centimeters the first unit, it was counted one error. If the trail of the cannon was found in the second zone, it was counted as two errors; if in the third zone, as three errors. Thus, if the mark of the cannon was found off the track twice in the first zone, once in the second zone and once in the third zone, the score would be seven errors. The distance was measured from the point at which the cannon left the track to

the most distant point that the cannon reached before it returned to the track.

Results

The third experiment shows a clear break between the two year old group and the three and four year old groups. Not one of the two year olds completed this experiment. Of the three year old group, two succeeded and two did not; the two who failed undoubtedly did so because of emotional difficulties to be discussed later. All of the four year old group completed the experiment, but three of them, subjects B, F, and G, failed on the first trial the first day.

Subject F was so upset by her first trial that she was not given a second trial that day, but B and G succeeded on the second trial although their time and error score was well above the mean, as is shown in table 4. On the second day subject F made no objection to trying again and did remarkably well. On both trials both her time and error scores were below the mean for the group. In fact this subject, with one trifling exception, improved steadily not only from day to day but from trial to trial. Her final score, 11 seconds, with no errors, was the best final score made by anyone, and her time was also the best made by any subject in any trial, although there were three other records made without errors.

The best initial score in both time and errors was made by subject H, 45 seconds and 1 error. He then slumped, becoming worse until on the second trial on the second day his time score was 149 seconds with 6 errors. Then he began to improve slowly and fin-

TABLE 4
Time and error score—four year group

SUBJECTS	WITHOUT MIRROR		1ST DAY				2ND DAY				3RD DAY				4TH DAY			
	T*	E†	1st		2nd		1st		2nd		1st		2nd		1st		2nd	
			T	E	T	E	T	E	T	E	T	E	T	E	T	E	T	E
A	15	1	103	7	153	19	71	4	27	2	35	3	20	4	30	4	19	2
B	30	1	DNC	—	131	13	150	14	130	6	118	10	57	6	59	3	27	4
C	10	1	69	5	36	5	43	3	27	4	32	3	28	4	24	4	17	2
D	17	4	85	11	43	12	55	7	50	14	142	11	80	5	31	5	29	4
E	39	1	265	24	132	7	144	5	63	5	80	3	57	1	67	2	39	3
F	21	0	DNC	—	—	—	59	3	27	5	13	0	12	0	16	1	11	0
G	45	0	DNC	—	250	13	100	6	92	7	29	3	62	5	61	3	65	4
H	35	0	45	1	77	8	135	16	149	6	79	2	76	3	73	4	42	4
Totals....	212	8	567	48	822	77	757	58	565	49	528	35	394	28	361	26	249	23
Mean.....	26.5	1.6	113.4	9.6	117.4	11	94.6	7.2	70.6	6.1	66	4.3	49.2	3.5	45.1	3.2	31.1	2.8

* T is time in seconds.

† E is errors.

TABLE 5
Time and error score
Three year group

SUBJECTS	WITHOUT MIRROR		1ST DAY				2ND DAY				3RD DAY				4TH DAY			
	T*	E†	1st		2nd		1st		2nd		1st		2nd		1st		2nd	
			T	E	T	E	T	E	T	E	T	E	T	E	T	E	T	E
J	34	6	DNC	—	—	—	DNC	—	—	—	—	—	—	—	—	—	—	—
L	30	1	89	21	80	13	128	8	87	5	90	9	57	3	95	8	39	2
I	20	1	DNC	—	—	—	DNC	—	—	—	—	—	—	—	—	—	—	—
M	10	0	DNC	—	—	—	DNC	—	—	—	85	0	130	8	72	3	37	4
Totals....	94	8	89	21	80	13	128	8	87	5	175	9	187	11	167	11	76	6
Mean.....	23.5	2.6									87.5		93.5	5.5	83.5	5.5	38	3

Two year group

SUBJECTS	WITHOUT MIRROR		1ST DAY		2ND DAY	
	T	E	T	E	T	E
O	15	3	DNC	—	DNC	—
P	87	12	DNC	—	DNC	—
Q	16	4	DNC	—	DNC	—
R	45	12	DNC	—	DNC	—
S	DNC	—	DNC	—	DNC	—
T	20	3	DNC	—	DNC	—
U	DNC	—	DNC	—	DNC	—
V	DNC	—	DNC	—	DNC	—
W	8	0	DNC	—	DNC	—
X	DNC	0	DNC	—	DNC	—

* T is time in seconds

† E is errors.

ished with a final score of 42 seconds with 4 errors. H was the youngest child in the four year old group, and the observer believes that the explanation of his record is lack of sufficient motivation. He was interested in the first trial and thereafter became careless, but finally began to improve again.

The longest first trial was made by subject E, 265 seconds, who also in that trial made the most errors, twenty four. E improves with regularity from day to day, his final score being 39 seconds with three errors. (Subject C's record is typical; see Plates II and III.)

In spite of individual differences, the mean of the four year old group shows steady improvement in both time and error scores from day to day and of the second trial over the first, with the one exception that the second trial on the first day is slower and shows more errors than the first trial on the first day. (See fig. 4.) In this group, all but one subject, G, made their best time in the final trial, and of these seven, four also made the fewest errors in the final trial.

In the three year old group, we have two subjects, J and I, who refused to finish the experiment. (See table 5.) J, who with direct vision took 34 seconds and made 4 errors, took his hand away from the cannon after ninety seconds with the statement, "I can't do it" and thereafter refused to revise his opinion. On the three succeeding days, he would accompany observer to the experimenting room without demur, seat himself in the chair and after one or two efforts to make the first turn would desist, folding his hands in his lap and repeating in a whiny tone, "Can't do it."

Although the result was the same, subject I's behavior was very different. With direct vision, he finished in 20 seconds with only 1 error. On the first trial with the mirror, he struggled for 137 seconds and then suddenly shouted, beginning to jump up and down, "It won't go! it won't go!" On being urged to try a little longer, he tried to look under the screen and had to be forcibly restrained. Whereupon he said, "I won't do it any more,"

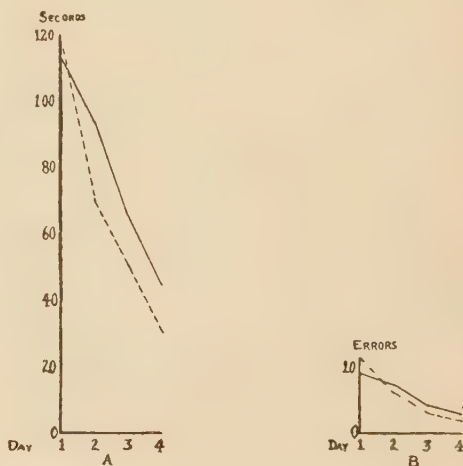
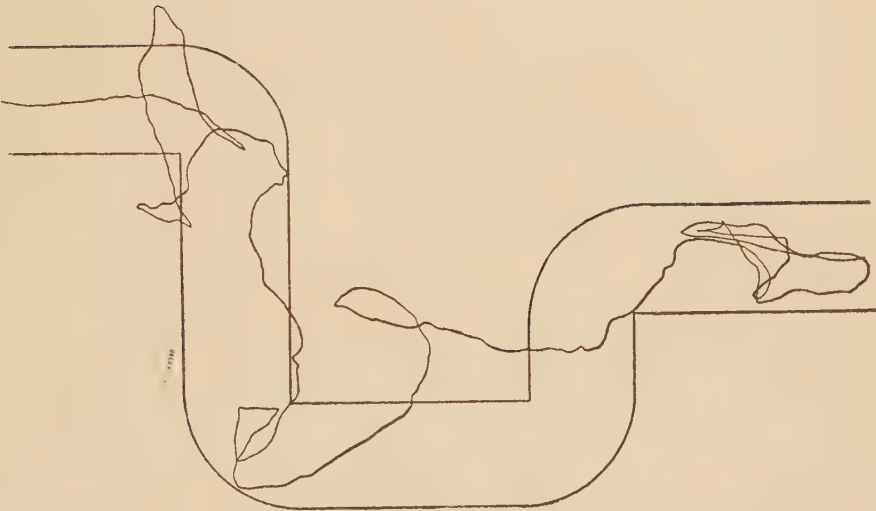


FIG. 4. A: MEAN TIME FOR PUSHING CANNON ALONG PATH, FOUR YEAR OLD GROUP; B: MEAN ERRORS

———— first trial; - - - - - second trial

and he would not. On the second day something of the same sort occurred, only this time he gave up after forty seconds. On the third and fourth days he pulled the cannon out from under the screen and pushed it along on top of the screen, never once making an effort to do the test as instructed. The observer later tried a special inducement, offering him a cannon like the experimental one to keep, if he would try to do the experiment, but he screwed himself up into a ball of



SUBJECT C. FIRST TRIAL, FIRST DAY. TIME: 69 SECONDS; ERRORS: 5

rebellion and said "It won't go and I won't try to make it go."

Only one subject in the three year old group succeeded the first trial. This was subject L, who took 89 seconds and made 21 errors on the first trial, but in the final trial she had cut down her time to 39 seconds and her errors to two. Subject M, the youngest child in the three year group, struggled valiantly until the five minutes were up, never getting beyond the first curve and remarking once, dispassionately, "It always goes that way," meaning the wrong way. He did not want to try again that day, but came willingly the next experimenting day. This time he succeeded in reaching the last turn just as his time was up, but seemed unwilling to make a second attempt that day. On the third day, he was successful in 85 seconds without a single error, on the first trial. On the second trial, which he wanted to make, he took 130 seconds and made 8 errors. Was this caused by fatigue? On the fourth day, his time was 72 seconds with 3 errors on the first trial, and 37 seconds with 4 errors on the second trial.

The reaction of the two year old group to the mirror part of the experiment was uniform, but surprising differences developed in the direct vision part of the test. Four of the ten two year old subjects could not, or would not, do even the direct vision part of the experiment. They seemed not to understand what was wanted, and just pushed the cannon aimlessly back and forth without regard to the path. Although they were given a second trial on the second day, they again failed completely. These four subjects were

S, V, U, and X, among the youngest children in the group, X being the youngest. But W, the next to youngest made a perfect record in 8 seconds with direct vision. He was hopelessly lost, however, with the mirror and just pushed the cannon back and forth, back and forth till the time was up.

The six subjects who succeeded in the direct vision trial were given two trials with the mirror, one right after the direct vision and one on the next experimenting day. As they showed no change in behavior whatever, unless perhaps more boredom and tendency to play on the second day than on the first, they were not given any further tests.

Summary

This experiment is interesting not only as showing up clearly the mirror adaptability of different age groups but also the cleavage between the two and three year old performance in other test situations, i.e., the failure of nearly half of the two year olds to do the direct vision part of the experiment. The increased difficulty of this experiment also brought out strongly the emotion connected with the effort to learn the new hand and eye coordinations.

SUMMARY AND CONCLUSIONS

In order to ascertain whether very young children could learn new eye and hand coordinations three experiments were devised. First, a simple task of picking objects up and putting them in a cup, the cup and objects being visible only in a mirror; second, an experiment with foot movements

in which the subjects pushed a disc with their foot from one position to another, foot, disc, and goal seen only in a mirror; and third, an experiment in which the subjects pushed a toy cannon along a path guided by the pattern seen in a mirror. In the second and third experiments, a pencil mark was left by the disc and cannon showing the course pursued on the way to the goal.

The subjects ranged in age from two to five years and were divided into three age groups, two, three, and four year old groups. There were 27 children in the first experiment and 22 in the second and third experiments. There were more boys than girls.

All three experiments show definite learning, and all three experiments show clear age differences, these differences becoming more marked as the difficulty of the experiments increases. All the subjects completed the first experiment, all the four year olds completed the second experiment as did all but one in each of the other age groups. None of the two year olds completed

the third experiment. Only half of the three year olds but all of the four year old group finished the third experiment.

Conclusions

The results of the three experiments used in this investigation are so definite and clear cut that in spite of the few subjects used certain conclusions seem justifiable. Children as young as two years acquire skill in tasks requiring new hand and eye coördinations in movements that are in opposition to those demanded in the ordinary environment. Young children learn such new habits more slowly than do adults, and learning proceeds more rapidly and more accurately as age increases. Age differences in adaptation to such situations as the mirror experiments present, are closely related to the complication or increasing difficulty of the coördinations involved. Mirror experiments bring out emotional tendencies in children that merit consideration in the guidance of the child.

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